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March 23, 2001 L. Nelson
Date Express Mail Label No.: EL 846224369 US

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SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT I, Reiko Kondo, a citizen of Japan residing at Kawasaki, Japan have invented certain new and useful improvements in

MAGNETIC HEAD USING A MAGNETO-RESISTIVE EFFECT

of which the following is a specification : -

TITLE OF THE INVENTION

MAGNETIC HEAD USING A MAGNETO-RESISTIVE EFFECT

CROSS-REFERENCE TO RELATED APPLICATION

The present application is based on Japanese priority application No.2000-131438 filed on April 28, 2000, the entire contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

The present invention generally relates to magnetic recording of information and more particularly to a high-sensitivity magnetic head for use in a magnetic disk drive for reading information from a magnetic disk by utilizing magneto-resistive effect.

A magneto-resistive head that uses magneto-resistive effect for reading magnetic information from a magnetic disk has an advantageous feature in that it provides an output signal more or less independently to a scanning speed of the magnetic head over a magnetic disk, on which information is recorded in the form of minute magnetic dots. Thus, a magneto-resistive head is suitable for a use in high-density magnetic disk drives in which a magnetic head is required to reproduce information form magnetic dots that are recorded on the magnetic disk surface with high density and reduced mutual separation.

With the progress in the art of high-density magnetic recording, the demand imposed on a magnetic head for detection of high-density magnetic information is becoming more and more stringent. In order to reproduce information form minute magnetic dots formed on a magnetic disk with rapidly reducing bit length and track width, it is necessary to increase the sensitivity of the magnetic head

accordingly.

FIG.1A shows the construction of a magneto-resistive head 10 used in conventional high-density magnetic disk drives.

Referring to FIG.1A, the magneto-resistive head 10 includes a magneto-resistive film 11 for detection of magnetic field, wherein the magneto-resistive film 11 changes a resistance thereof in response to a magnetic field applied thereto, and the magneto-resistive head 10 achieves the detection of the magnetic field by measuring the magneto-resistance of the magneto-resistive film 11.

For this purpose, electrodes 13A and 13B are provided on the magneto-resistive film 11 for causing to flow a sensing current through the magneto-resistive film 11, wherein the electrodes 13A and 13B are respectively provided on domain control regions 12A and 13B disposed at both lateral sides of the magneto-resistive film 11 for domain control of the magneto-resistive film 11. More specifically, the domain control regions 12A and 12B are formed of a hard magnetic material such as CoCr having a large coercive force or an anti-ferromagnetic film such as PdPtMn and eliminates formation of magnetic domains in the magneto-resistive film 11. As a result of formation of the domain control regions 12A and 12B, the magneto-resistive film 11 takes a mono-domain structure, and Barkhausen noise, caused as a result of movement of domain walls, is effectively eliminated.

In the magneto-resistive head 10 of FIG.1A, the magneto-resistive film 11 may be formed of a single-layer anisotropic magneto-resistive (AMR) film or a giant magneto-resistive (GMR) film, wherein the GMR film may be a spin-valve film or a tunneling magneto-resistive (TMR) film. A spin-valve film includes an anti-ferromagnetic pinning layer, a ferromagnetic pinned layer provided adjacent to the

anti-ferromagnetic pinning layer, and a ferromagnetic free layer provided in the vicinity of the ferromagnetic pinned layer via an intervening non-magnetic conducting film. A TMR film includes an anti-ferromagnetic pinning layer, a ferromagnetic pinned layer provided adjacent to the anti-ferromagnetic pinning layer, and a ferromagnetic free layer provided in the vicinity of the ferromagnetic pinned layer via an intervening tunneling insulation film. In the case a GMR film or TMR film is used for the magneto-resistive film 11 in the magnetic head 10 of FIG.1A, it should be noted that the domain control regions 12A and 12B controls the domain formation in the ferromagnetic free layer by causing a localized pinning of magnetization in the ferromagnetic free layer.

In view of the fact that the domain control regions 12A and 12B achieve the desired domain control in the ferromagnetic free layer by causing a local pinning of magnetization as noted above, there are formed dead regions in the magneto-resistive film 11 designated as INS in FIG.1A in which the magnetization of the free layer does not change substantially even when a magnetic field from a magnetic dot on the magnetic disk is applied.

In the construction of FIG.1A, the sensing current from the electrode 13A to the electrode 13B inevitably flows through a path that crosses the dead regions INS and the sensitivity of magnetic detection is deteriorated.

In view of the drawback of the magnetic head 10 of FIG.1A, there is proposed a magneto-resistive head 20 having a so-called overlaid structure as represented in FIG.1B, in which electrodes 23A and 23B respectively corresponding the electrodes 13A and 13B are provided on domain control regions 22A and 22B respectively corresponding to the domain control

regions 12A and 12B of FIG.1A, such that each of the electrodes 23A and 23B includes a tip-end region 23A-a or 23B-b that extends over a magneto-resistive film 21 in the direction of the other, opposing electrode, beyond the dead region INS. According to the construction of the magneto-resistive head 20 of FIG.1B, the sensing current flows through the magneto-resistive film 21 corresponding to the magneto-resistive film 11 while avoiding the dead regions INS, and the sensitivity of the magneto-resistive sensor 20 is improved.

Further, there is proposed a magneto-resistive head 30 having a CPP structure as noted in FIG.2, in which the sensing current is caused to flow perpendicularly to a magneto-resistive film 31.

Referring to FIG.2, it can be seen that domain control regions 32A and 32B are provided at both lateral sides of the magneto-resistive film 31 for magnetic domain control, wherein the sensing current is caused to flow through the magneto-resistive film 31 perpendicularly between an upper electrode 33A provided on the magneto-resistive film 31 and a lower electrode 33B provided under the magneto-resistive film 31. The magnetic head 30 having the CPP construction noted above is advantageous for high-sensitivity detection of the magneto-resistance change caused by an external magnetic field. In the magneto-resistive head 30, too, it is possible to use a GMR film such as a spin-valve film or TMR film for the magneto-resistive film 31.

On the other hand, the magneto-resistive head 30 of the CPP structure of FIG.2 has a drawback, while being able to increase the sensitivity of the magneto-resistive film 31 itself, in that the dead regions INS are formed within the path of the sensing current as a result of local magnetic pinning action of the domain control regions 32A and 32B similarly to

the magneto-resistive head 10 of FIG.1A and that the existence of the dead regions INS in the sensing current path reduces the effective core width TW of the magneto-resistive film 31 used for magnetic detection. Because of the reduced effective core width TW, the magnetic head 30 can detect only a part of the magnetic information recorded on a magnetic track of the magnetic disk even in such a case the magnetic head 30 has a geometrical or so-called optical core width corresponding to the track width on the magnetic disk. Further, the dead regions INS tend to cause a disturbance in the sensing current flowing through the magneto-resistive film 31 perpendicularly.

In the case of the magneto-resistive head 20 of FIG.1B, on the other hand, the problem of the sensitivity degradation caused by the dead regions INS is avoided successfully by providing the protruding tip-end regions 23A-a and 23B-b for the electrodes 23A and 23B such that the sensing current is caused to flow preferentially in the geometrical or optical core region defined between the opposing tip-end regions 23A-a and 23B-b, as noted before.

On the other hand, the magneto-resistive head 20 of FIG.1B has a drawback in that the protrusion of the tip regions 23A-a and 23B-b beyond the dead regions INS tends to cause an increase in the effective core width TW over the geometrically defined optical core width, as a result of the distribution profile of the sensing current formed underneath the tip-end regions 23A-a and 23B-b protruding beyond the dead regions INS. It should be noted that exact control of the process for forming the electrodes 23A and 23B with the tip-end regions 23A-a and 23B-b in exact alignment with the inner edge of the dead region INS has been difficult. Further, the magneto-resistive head 20 of FIG.1B tends to suffer from the problem of positional offset of the tip regions 23A-a and 23B-b

with respect to the core region TW. It should be noted that the domain control regions 22A and 22B are formed by a process different from the process of forming the electrodes 23A and 23B, and because of this, it is generally inevitable that such a positional offset is caused.

SUMMARY OF THE INVENTION

Accordingly, it is a general object of the present invention to provide a novel and useful magneto-resistive head wherein the foregoing problems are eliminated.

Another and more specific object of the present invention is to provide a magneto-resistive head having an improved sensitivity and a fabrication process thereof.

Another object of the present invention is to provide a method of fabricating a magnetic head, comprising the steps of:

forming a magneto-resistive film;

forming a resist film on said magneto-resistive film;

patterning said resist film to form a resist pattern; and

causing a shrinkage in said resist pattern.

According to the present invention, it is possible to form various patterns of the magnetic head in ideal alignment by using the resist pattern and the shrunken resist pattern in respective patterning processes.

Another object of the present invention is to provide a magnetic head, comprising:

a magneto-resistive film having a ferromagnetic free layer at a top part thereof, said ferromagnetic free layer changing a magnetization thereof in response to an external magnetic field;

a pair of magnetic domain control patterns

provided on said ferromagnetic free layer, each of said magnetic domain control patterns causing a pinning of magnetization in said ferromagnetic free layer in the vicinity thereof;

a first electrode provided on said ferromagnetic free layer in contact therewith at a region located between said pair of magnetic domain control regions; and

a second electrode provided in electrical contact with a bottom surface of said magneto-resistive film.

Another object of the present invention is to provide a method of fabricating a magnetic head, comprising the steps of:

forming a magneto-resistive film on a substrate such that said magneto-resistive film includes a ferromagnetic layer on a top part thereof;

depositing a resist film on said magneto-resistive film such that said resist film covers said ferromagnetic layer;

patterning said resist film to form a resist pattern;

depositing a high-coercive magnetic film having a coercive force larger than a coercive force of said ferromagnetic layer in said magneto-resistive film on said magneto-resistive film while using said resist pattern as a mask, to form a pair of high-coercive magnetic regions at both lateral sides of said resist pattern;

causing a shrinkage in said resist pattern to form a shrunken resist pattern;

depositing an insulating film on said magneto-resistive film such that said insulating film covers said high-coercive magnetic regions and further said shrunken resist pattern;

removing said shrunken resist pattern together with a part of said insulating film covering

said shrunken resist pattern so as to expose a part of said magneto-resistive film on which said shrunken resist pattern has been provided; and

depositing an electrode layer on said insulating film such that said electrode layer makes a contact with said exposed part of said magneto-resistive film.

According to the present invention, it becomes possible to inject a sensing current into the ferromagnetic free layer from the first electrode while avoiding the dead regions in which local pinning of magnetization is caused by the magnetic domain control regions. Thereby, the sensitivity of magnetic detection is effectively maximized in a magnetic head having a CPP structure. By providing the magnetic domain control regions over the ferromagnetic free layer, the pinning of magnetization is caused primarily in the part of the ferromagnetic free layer located right underneath the domain control regions. Thus, no substantial dead region is formed in the core region of the magnetic head used for detecting magnetic signals from a magnetic track formed on a magnetic disk.

Another object of the present invention is to provide a magnetic head, comprising:

a magneto-resistive film;

a pair of magnetic domain control patterns provided at both lateral sides of said magneto-resistive film, each of said magnetic domain control patterns causing a pinning of magnetization in said magneto-resistive film in the vicinity thereof;

a pair of electrodes provided respectively on said pair of magnetic domain control regions with a mutual separation from each other, each electrode having a tip-end part extending over said magneto-resistive film toward the other electrode,

wherein each tip-end part extends beyond

said domain control region, on which said electrode having said tip-end part is provided, with a protruding distance of 0.25 μm or less.

Another object of the present invention is to provide a method of fabricating a magnetic head, comprising the steps of:

forming a magneto-resistive film on a substrate;

forming a resist film on said magneto-resistive film;

patterning said resist film to form a resist pattern;

patterning said magneto-resistive film while using said resist pattern as a mask to form a magneto-resistive pattern;

depositing a magnetic film having a coercive force larger than a coercive force of said magneto-resistive film while using said resist pattern as a mask, such that a pair of high-coercive magnetic regions having a large coercive force are formed at both lateral sides of said magneto-resistive pattern from said ferromagnetic film;

causing a shrinkage in said resist pattern;

depositing a conductive layer on said magneto-resistive film while using said shrunken resist pattern as a mask, such that said electrode layer forms a pair of electrode patterns respectively covering said high-coercive magnetic region.

According to the present invention, it becomes possible to reduce the deviation between the geometrical or optical core width and the effective or electrical core width in a magneto-resistive head having an overlaid structure, by employing a self-alignment process that uses a shrunken resist pattern for controlling the protruding distance of the tip end part of the electrodes. As a result of the use of the self-alignment process, it becomes possible to reduce

the protruding distance of the tip-end part of the electrode beyond the high-coercive region formed underneath to be 0.25 μm or less. Thereby, the injection of the sensing current is caused only from the very tip end of the protruding tip-end part, while successfully avoiding unwanted injection of the sensing current from the remaining part of the tip-end part protruding beyond the dead region. Thereby, the sensitivity of magnetic signals from a narrow magnetic track is improved.

Other objects and further features of the present invention will become apparent from the following detailed description when read in conjunction with the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS.1A and 1B are diagram showing the cross-sectional structure of a magneto-resistive head according to a related art;

FIG.2 is a diagram showing the cross-sectional structure of a magneto-resistive head according to another related art;

FIGS.3A - 3H are diagrams showing the fabrication process of a magneto-resistive head according to a first embodiment of the present invention;

FIGS.4A - 4F are diagrams showing the fabrication process of a magneto-resistive head according to a second embodiment of the present invention;

FIG.5 is a diagram showing the relationship between an effective core width and an electrode overlap in the magneto-resistive head of the second embodiment; and

FIG.6 is a diagram showing the construction of a magnetic disk drive according to a third embodiment of the present invention in a plan view.

DETAILED DESCRIPTION OF THE INVENTION

[FIRST EMBODIMENT]

FIGS.3A - 3H show the fabrication process of a magneto-resistive head 100 of CPP type according to a first embodiment of the present invention.

Referring to FIG.3A, a bottom electrode film 103 and a magneto-resistive film 104 are deposited consecutively on a substrate 101, wherein the bottom electrode film 103 may be a Pt film while the magneto-resistive film 104 may be a GMR film having a spin-valve structure. For example, the magneto-resistive film 104 may include a consecutive stacking of an anti-ferromagnetic film of IrMn forming a pining layer, a ferromagnetic film of NiFe having a magnetization pinned by the anti-ferromagnetic film and acting as a pinned layer, a non-magnetic film of Cu acting as a non-magnetic conducting layer, and a ferromagnetic film of NiFe forming a free layer having a magnetization that changes in response to an external magnetic field, wherein the anti-ferromagnetic film may be replaced by a ferrimagnetic film having a stacked structure of PdPtMn/CoFeB/Ru/CoFeB. Further, the magneto-resistive film 104 may be formed of a TMR film in which an anti-ferromagnetic pinning layer of PdPtMn, a ferromagnetic pinned layer of NiFe, a tunneling oxide film of AlO_x and a ferromagnetic free layer of NiFe are stacked consecutively. Alternatively, the magneto-resistive layer 104 may be formed of a single layer of anisotropic magneto-resistive (AMR) film such as NiFe or an artificial superlattice structure such as [CoFe/Co]10.

In the construction of FIG.3A, it should be noted that the magneto-resistive film 104 includes the magnetic free layer at the top part thereof, as represented by a layer 105. Thus, the free layer 105 may be a NiFe ferromagnetic film in the case the magneto-resistive film 104 has a spin-valve structure